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Procedia - Social and Behavioral Sciences 120 (2014) 213 – 223

Procedia
Social and Behavioral Sciences

The 3rd International Geography Symposium - GEOMED2013

Dependence of the medieval settlements and historical roads to the natural environment around the deserted castle in Zvolen (Slovakia)

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Abstract

The main aim of research is identification of the medieval settlements and historical roads in dependence to natural factors. Attributes of natural environment had limited their location in landscape during the medieval ages. Medieval settlements were studied in the region around Zvolen. Relatives of historical roads to relief attributes are studied in the forests around the castle. They are identified by global position navigation system in the field. Exact position and analyses of parameters are computed in the digital models of terrain. They are elaborated from point clouds gained by aerial laser scanning by light detection and ranging method.

Keywords: medieval settlements; historical roads; natural environment; aerial laser scanning.

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doi:10.1016/j.sbspro.2014.02.098

1. Introduction

Object of our study are anthropogenic relief forms of the historical medieval settlements and roads. They represent a specific feature of the cultural landscape. Anthropogenic relief forms have persisted in the landscape for long historical periods (Slamova and Jancura, 2005), and they are significant part of the landscape's heritage which should be preserved (Ivan, 1993; Wielgus and Srodulska-Wielgus, 2003). The main aim of research is identification of relations of the medieval settlements and historical roads to the specific natural conditions. Zvolen has been situated on the historical crossroad for a long time. We have motivation to verify and confirm the existence of the historical road system in the field around the Deserted castle. We would like to bring new point of view on research about identification of anthropogenic relief forms, especially historical roads, and possibilities of aerial laser scanning application into the scientific fields of archaeology and landscape ecology.

Historical roads have persisted only locally in landscape till today. We can find them mostly in the forests. Extensive research about identification of historical roads in the field did Klein (1978); Ivanic (2011) and Maliniak (2009) provided comprehensive overview of the historical literature sources about the historical roads in Slovakia. As Toda (2012) observed, identification of the historical roads in the field can bring more information then we can extract from the written historical sources or more current cartographic data. Examples about mapping the historical roads in the field present works of foriegn authors: Bolina, Klimek (2010) in Czech Republic; Tsoar, Yekutieli (1993) in Israel; Smekalova and Smekalov (2006) mapped roads and related archaeological sites in the European Kimmerian Bosporos.

Identification of anthropogenic relief objects by aerial laser scanning method, especially identification of linear objects (forest road network, proprietorial boundaries in a forest), is the main research subject of the Department of Forest Management and Geodesy at Technical University in Zvolen (Sackov, Smrecek and Koren, 2013; Chudy, Sadibol and Jadudova, 2012; Chudy and Sadibol, 2013). Aerial laser scanning works on the principle of laser emission pulses to the object and then detects their reflection, while simultaneously recording the position and inclination of the supporting device, the direction of transmitted pulse and time required for this activity. On the recorded data bases there can be calculated spatial coordinates of points of the objects parts from which the pulse is reflected. For identification of linear objects under the forest cover it is important to record terrain under the forest vegetation. This is provided by high transmission frequency of rays and various size of ray footprint. This enables to obtain multiple pulse reflections from one pulse (part of the light pulse is reflected from the top of the treetops and part of the beam passes through the gaps between the leaves to the ground terrain). In this way it is possible to record the overlapping objects. Reliability of the captured field depends on the number of recorded points per unit area (m^2). It is affected by height and speed of the airplane using scanning device, further by the density of vegetation cover (crown canopy, kind of the tree species), seasons, geomorphology and terrain configuration.

2. Geological, geomorphologic and historical characteristics of the studied areas

We observed the medieval archaeological sites in the wider area around Zvolen. Studied area with archaeological sites is situated in the central part of Slovakia, in the Javorie Mts., Kremnicke vrchy Mts. and Zvolenska kotlina basin. We studied ancient routes which are situated in the forests southwards to the Deserted castle near Zvolen. Deserted castle lies on the confluence of three rivers: Hron, Slatina and Neresnica.

The massif of the Deserted castle was formed by endogen processes mostly during the later tectonic period. The lithology environment, around the Deserted castle, the Velky vrch hill and Velka Straz hill, was formed in several phases during the Neogene volcanism. Rivers correspond with the main tectonic faults and they have started to carve antecedent valleys into the massifs of neovolcanic rocks after the neotectonic movement in the Pleistocene period. Tectonical and climatic oscillations of the environment create conditions for genesis of the accumulation terraces which are situated today in several height levels above the rivers. During the semi-final Riss continental glaciations (it is Saal after the Nordic classification of the glaciation) the Strazov horst was uplifted about the 10-15 m (Konecny et al., 1983). This uplift had blocked the river course across the Strazov horst and the river moved into the area of tectonical weak segment, to the lower Southern part of the basin between the massif of the Deserted castle and Velka Straz hill. The river carved geomorphologic form - canyon. It divides the Velka Straz hill from the rest of the Javorie stratovolcano. After the contemporary hydro-geological situation of the SHMU 2010 report (Caucik, et

al., 2011) there occur several permanent groundwater springs with good water potential in the studied area. These water resources are today used as sources of drinkable water for the Zvolen town and villages. The best reservoirs are in the Quaternary sediments of the river Hron and good reservoirs are in the neovolcanic mountains. We assume that they had similar or higher water potential in the past.

Deserted castle is the most important medieval archaeological site in the region. Early medieval urbanized areas strongly correlate with history and location of the Slavic settlements. There is not exactly dated Slavic colonization of the Zvolenska kotlina basin before 7th century AD. Typical position for a Slavic settlement has the site - Zvolen castle hill, near to the city centre. It has position on cut-off meander core, at the confluence of the Hron and Slatina rivers. Archaeological research uncovered under the layers of the gothic castle a massive rectangular object (Schonweitzova, 1972). The oldest dated Slavic settlement near Zvolen is the site Haputka (Fusek 1994; Hanuliak, et al., 2000) which is situated nearby the rampart system of Drahy under the Deserted castle. Further we document Slavic settlements which were settled before and during the Great Moravian Empire near Zvolen, in the Deserted castle surroundings, for instance: Kriva Put (Rejholcova, 1971), Pod bralami (Zebrak, 1982), contemporary area of Technical University (Macelova, 2009), the central square of Zvolen (Beljak, Pazinova, 2012) and some findings are on the rivers' confluence (Sekier and Slatina streams) in Motova and Lieskovec village. Significant upland sites and fortresses were established on the hills above the town in the last third of the 9th century and in the 10th century. The most important site - Priekopa is situated on the confluence of the rivers Slatina and Neresnica in Motova (Macelova, 1993). The fortress vanished in the 11th century in early Arpad period.

3. Research material and methods

3.1. Material

The research is based on application of methods used in archaeology, geology, geodesy and landscape ecology. We used GNSS (Global Navigation Satellite System) Garmin serial 2008 (with declared position divergence 3 m in case of low signal) for definition of basic geographical position of the historical relief objects. GNSS data are transformed from the geographic geo-reference system WGS 84 to the projection system S-JTSK Ferro/Krovak (EPSG 2065) of the national maps. Data from aerial laser scanning (LIDAR) were provided by the Department of Forest Management and Geodesy, Technical University in Zvolen. Scanning was performed in 2012 (April) by scanner Riegl LMS Q680i with height of flight 600-900 meters, with a scanning angle 60° (FOV), an average overlap 40% and a frequency of 122 Hz (SR) by Photomap Ltd. Acquired point clouds have a density of about 5 points per m^2. Identification of historic roads was made after processing (classification filter method) "raw" data into two classes - terrain and vegetation and exported to LAS 1.2 format (by support Photomap, Ltd.) by software companies RIEGEL Laser Measurement system GmbH and Terrasolid Ltd. (Fig. 1a) and after processing of data was done digital model of terrain (Fig. 1b)

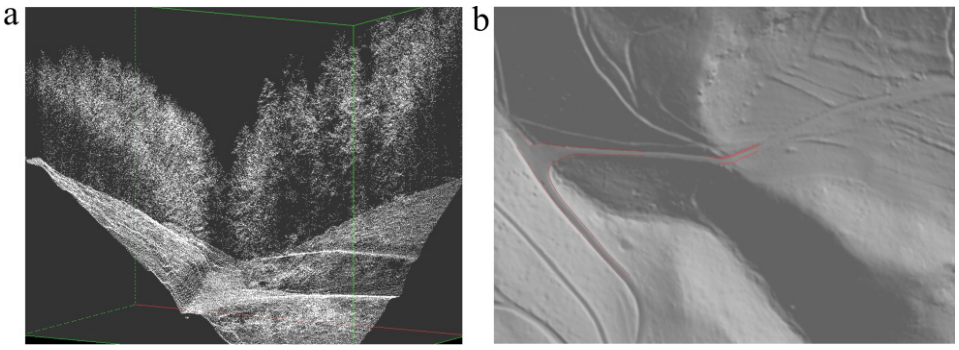

Fig. 1. (a) point clouds: vegetation and terrain; (b) digital model of terrain.

Maps of the results were elaborated by GNU applications Quantum GIS 1.8.1 and GrassGIS 2.4.2. RC2. Geological maps of scale 1:50,000 were downloaded from web map server:

http://mserver.geology.sk:8399/arcgis/services/geology_wms/MapServer/WMSServer?. Maps are provided under the rules and support of Open Geospatial Consortium. Graphic layouts were done in CorelDraw GraphicSuiteX4^{TM}.

3.2. Methodical steps

Dependence of the early medieval settlements location to natural conditions around the Zvolen town:

We identify Slavic and early medieval sites (total no. 24) in the field (total area is 100 km^2); Archaeological investigations were done between 1960-2012 in the region; We evaluate occurrence of ground water springs, absolute altitude and geological formations in relation to location of the historical settlements in landscape. Parameters of altitude where measured by GNSS and corrected according to basic topographic maps of Slovakia.

Field research (9.6.-29.9.2012) of historical roads:

We present results about identification of historical roads around the Deserted castle in area 23,19 km^2; Substantial information for identification of historical roads in terrain provided forest engineer Dusan Fertal, who had 40 years of practical experiences with forest roads building and he spent several years in the studied area; We identified "guide" trees which were necessary for orientation in the forests for medieval wayfarers; Old roads are identified according to the remains of hollow ways; In case that hollow ways enumeration is not possible due to a huge concentration on the slope, we mapped the entire area of the hollow ways; We interpret in the map each individual road as well as it is described by short text including basic statistics: length (m), height above sea level (m/ASL), no. of unique values of the points, mean, minimum, maximum;

Specifically, we evaluate historical roads. We evaluate the sum of lines length of roads in the polygons of slope grade categories; We used categories which are significant for mapping of meso-relief forms in geomorphology and geo-ecology (Sklenicka, 2003): less than 3° is plane/flat; 3° - 7° is gentle slope; 7 °- 12° is middle slope; 12° - 17° is steep slope; 17 - 25° is very steep; more than 25° is cliff; Specific category for our evaluation is category 3°-12°, because it is relevant to technical parameters for building of the forest roads of the 1st and the 2nd category (accessible for the machines during all seasons in the year) as it is described in the Forest Transportation Network norm (Klc, 2000); Authors define the most important slope grade 12% (6,84° belongs to the category of gentle slopes) for the roads of this category;

Study of the historical roads location in relation to the natural conditions around the castle:

Relations were studied in closer area 5,14 km^2 around the castle. We evaluate geological base and meso-relief forms of the historical roads; We interpret information about the position of the historical roads in relief in relation to location of the medieval settlement (Deserted castle) and other sites.

Comparison of the GNSS data and data of airborne laser scanner (LIDAR):

We compare position of the historical road mapped by GNSS in the field with position of the road on the LIDAR DTM; We assess the consistency (evaluated as polygon intersection in GIS) of data between length of the historical road mapped by GNSS with the buffer zone 3 m (declared position error) and the polygons of the historical road on the LIDAR DTM; We evaluate the proportion of slopes which are steeper more than 12% to the total length of the historical road (these steep segments of roads were difficult for animal transport which usually tragged heavy coaches); We evaluate slope grade of the historical road in percents (%) and degrees (°) and we classified absolute (m) and relative (%) presence of the slope grade category in total length of the road ; Counter lines are displayed in elevation interval of 3 m.

4. Results

4.1. Location of the medieval settlements around Zvolen in relation to natural limits

Natural conditions markedly affected location of the medieval settlements and road network. Deserted castle (571 m ASL) is situated on the hill, nearly 250 m above the quaternary Pleistocene terraces. It appears as visual domain. The most of the sites - 16 is situated in altitude up to 350 m ASL, they occupy the river flat, cut-off meander inside the flat and terraces; 3 are situated up to 350 m ASL on the slopes around the flood plain, 2 sites are in altitude

between 430-465 m ASL and 1 site is situated in altitude between 465 - 486 m ASL (the Deserted castle, Lower castle) and 2 sites are in the altitude between 486 - 600 m ASL (Bukovinka and the Deserted castle, Upper castle). Prevailing part of the sites - 12 are situated on the Pleistocene river gravel terraces locally covered by diluvium; 5 sites are situated on the Neogene andesitic rocks and pyroclastic material; 4 localities have position on the Quaternary gravels and loam sediments of the rivers; 2 sites occupy gravel-loamy Quaternary deluvial sediments and fluvial cones (one of the site is the rampart with a ditch); 1 site (medieval church near Ostra Luka village) is situated on the Neogene basalts. From studied sites, 3 are dated only to early medieval period between 9^{th} -10^{th} century; during the period of Slavic tribes existed 10 sites; 2 sites are dated between 11^{th} -13^{th} century and the rest - 9 sites are dated between 14^{th} -16^{th} century (Late Middle Ages).

We observed that there is no dependence between position of the archaeological sites and underground water resources. The main reason is lack of information about local springs which are not signed in the official public maps. But according to our study of the geological situation we can expect that there existed well filled wells with quality water on the rivers' terraces where the most of the sites are situated. According to the geological base we can suppose that Neogene andesitic pyroclastic formations have bad water retention potential in the upper parts of the mountains, where the Deserted castle is situated. Lower situated localities up to 350 m ASL have fertile soil suitable for agriculture in close surroundings. These natural factors provide good conditions for the settlements development in the lower situated sites.

4.2. Basic statistics of the historical roads

Total length is 74,209 km of all roads which we identified in the field. Total number of mapped points is 196. Total length of mapped historical roads is 49,486 km. Total area of mapped hollow ways is 16,12 ha. Evaluation of altitude (m/ASL): mean – 434; min. – 288; max. - 580. We evaluate the sum of the historical roads lines length in the polygons of the slope's categories: 0°-3°/3,74 km; prevailing part of the roads: 26,76 km occur in the category 3°-12°; 10,93 km/12°-17°; 10,13 km /17°-25°; 2,47 km / 25°-45°.

4.3. Position of the historical roads in terrain, parameters of slope grade

Total length of the historical roads is 19163,121 m in closer area around the castle. We identified historical roads in relation to the geological formations (Fig. 2), because we observed in the field, that locally occur only one road in terrain and few meters further, the same road divides into the several hollow ways which occur in some places numerously (there are displayed as polygons with vertical lining) and they are locally very deep (more than 2 m). We supposed that this phenomenon is caused by different geological formations which are less resistant to the weathering processes and by this way they are more predisposed to the destruction by anthropogenic activities. When we evaluate abundance of the old roads inside the polygons of the geological formations we obtained numbers which do not confirm our assumption about positive relation between geological substrate and the depth and multitude of hollow ways (Fig. 2). There is located 1510,58 m of old roads in chaotic breccias of pyroclastic flows and coarse to blocky epiclastic volcanic breccias; 149,06 m of roads occur in dykes of amphibole-pyroxene andesitic rocks; 1160,09 m of roads occur in deluvial-fluvial wash sediments which are predominantly loamy with fragments and gravel (in mountain valleys); 1896,40 m of roads is in polygenetic slope loams, partly sandy to stony; 664,00 m of roads is in proluvial flood plain loams and sandy loams with gravels to half blocks (alluvial fan); 748,23 m of roads is in epiclastic, coarse to blocky, volcanic breccias of Javorie formation; 7941,92 m of roads is in epiclastic, coarse to blocky, volcanic breccias of Neresnica formation; 1168,29 m of roads occur in extrusive dome of andesites; 257,98 m of roads is in extrusive dome of pyroxene-amphibole andesite with garnet; 1953,48 m of roads occur in fluvial sediments (Holocene flood plain loams and sandy loams, sporadic gravelous-loamy); 584,35 m of road is in epiclastic, coarse to blocky, volcanic conglomerates in Neresnica formation; 374,38 m of roads is in lava flows of amphibole-pyroxene andesites; 754,35 m of roads is in redeposited pyroclastics with pumice-tuffaceous matrix. Hollow ways are the similarly numerous in the epiclastic volcanic breccias as well as in the amphibole-pyroxene andesites (lava flows, extrusive doms) in locality Drahy (locality name "Drahy" means in

English translation “roads”, in sense of old roads) and also in the similar close locality to the South, before saddle back. But there is no relation to geological conditions.

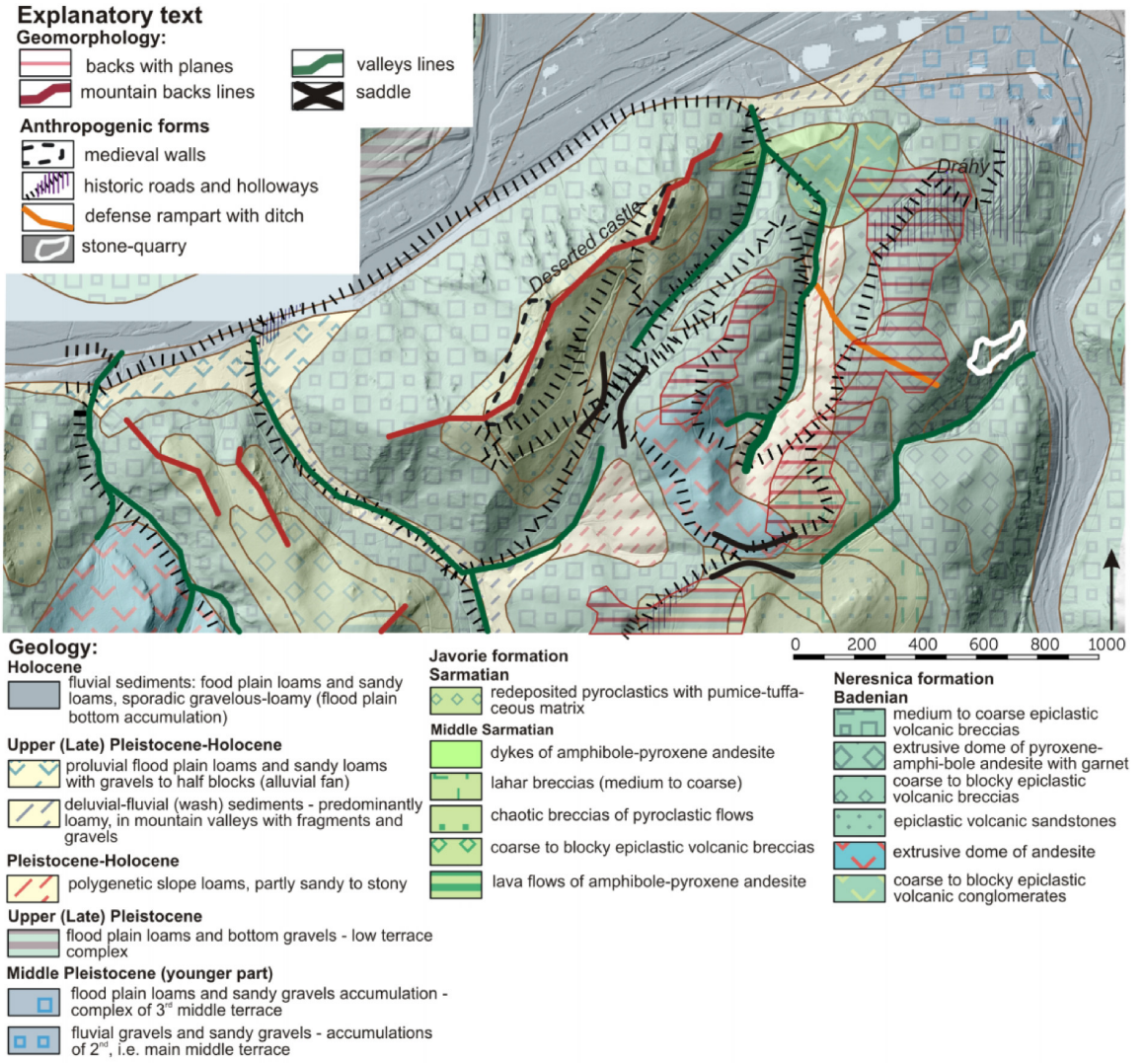

Fig. 2. Area around the Deserted castle where we studied historical roads and sites relatives to the land-forms, slope and geology.

We have some arguments that concentration of hollow ways in these localities could document strong intensity of traffic. When we evaluate geomorphology, we observed that there is situated only 10,2 % of the total length of old roads in flood plain. It confirms the statement that historical roads are usually situated outside of the river flat; 25,8% lies in area of Quaternary proluvial and deluvial sediments and the rest of the roads is situated on the slopes built by volcanic material. 4547,81 m (23,73%) lies in slope grade category 0°-7°, and this slope category corresponds mostly with alluvial flat plains in the valleys and saddle backs in the mountains. Prevailing part of the roads: 14615,31 m (76,27%) is situated on the slopes with declination more than 7°. Crossroads are situated mostly in the saddle backs and at the junctions of valleys streams. Only small part of roads is situated on the mountains backs and ridges. Very interesting is position of the rampart with a ditch. It is located very close to the Deserted castla and near locality called “Drahy”. It has position directly transverse to the historical road leading to Zvolen for

a long times. The rampart is dated by the radiocarbon method between 7th-8th century AD (Beljak, Pazinova, 2012). Deserted castle is located on the high hill, on the mountain ridge built of neovolcanic mostly pyroclastic andesitic rocks. It is spatially isolated from other hills by steep slopes and cliffs and entrance road is very steep (comparing to the criterion for building of the forest transportation roads). It has very good natural conditions to be well protected and moreover it can visually control wide region.

4.4. Comparison of the GNSS and LIDAR data

Anthropogenic relief (roads, ramparts and planes) is clearly visible as terrain anomaly in Figure 3, where it appears as green areas of the steep slopes or local small planes in surrounding relief with prevailing slope grade more than 25°. We compared data coincidence in short segment of old road before the entrance gate to the Deserted Castle. Total length is 393,95 m. We do not present slope grade evaluation of road from data obtained by GNSS in large scale maps. The reason is data inconsonance between GNSS data and data gained by LIDAR. Consistency of data about geographical position of the historical road appears only in the length of 235,52 m (60%) of the road (Fig. 3). We took into account position error of the GNSS declared by producer (3 m buffer zone around road) in data consistency evaluation. When we visually compare the road and buffer area of the historical road located by GNSS and displayed in LIDAR DTM (slope grade derivation), we can see, that according to GNSS data large part of the road lies in the category 17°-25°. But we did not observe such a steep slope in the field. This steep slope is not acceptable for the dense traffic with animals close to the main entrance gate of the castle.

Table 1. Detailed classification of road under the Deserted castle.

Slope declination categories units (%)	less than 12	12-20	20-30	more than 30
Slope declination categories units (°)	less than 6,84	6,84-11,31	11,31-16,70	more than 16,70
Length of road (m)	78,12	206,08	99,06	10,44
Relative length of road (%)	20	52	25	3

According to the LIDAR data we presented slope grade categories of the historical road segment in Table 1. Prevailing part of the road lies in the category of slope grade - middle slope (12-20% ; 6,84°-11,31°) and in the category - steep slopes (20-30%; 11,31°-16,70°).

5. Discussion

Specific natural conditions predestined the Deserted castle to keep watch on the strategic area with historical roads. The castle controlled space of forests spreading to the South. When the enemy threat had been getting intensive, defenders built the defence rampart. Very close to the rampart is the locality “Drahy” where is visible system of very deep hollow ways in terrain. Some literature sources mention important medieval trade routes called “via Magna” (Maliniak, 2009) that were situated around Zvolen. These routes forwarded from the South to Zvolen, and farther continued to the rich mining towns (copper, silver, gold was mined) in the central and Northern Slovakia. We compare our results with other authors (Slivka, 1990) and we can state that in close surroundings of the international and regional roads were concentrated settlements and significant castles. This is the case of the Deserted castle. We did similar investigation in the Turcianska kotlina basin (Slamova et al., 2012). Medieval settlements (13th century) were based mostly on the river flats and later founded settlements (14th-15th centuries) were based on the rivers terraces of the basin. It is different situation then we observed near Zvolen, because medieval settlements are located there mostly on the river terraces. Searching for explanation requires further study. Underground water is the main important factor for the settlement location as observed also other authors (Chrastina, 2009) and other essential natural actors are: availability of fertile, rich alluvial soil and fish (Clevis et al., 2006). The Deserted castle had problems with water, because pyroclastic material is bad retention reservoir for the ground water. There is no water resource in the upper part of the hills. This factor could cause castle decay, but

historically we have a tangible evidence of water tank construction on the Upper castle. It had provided potable water supply from the late 14th century till the end of the settlement.

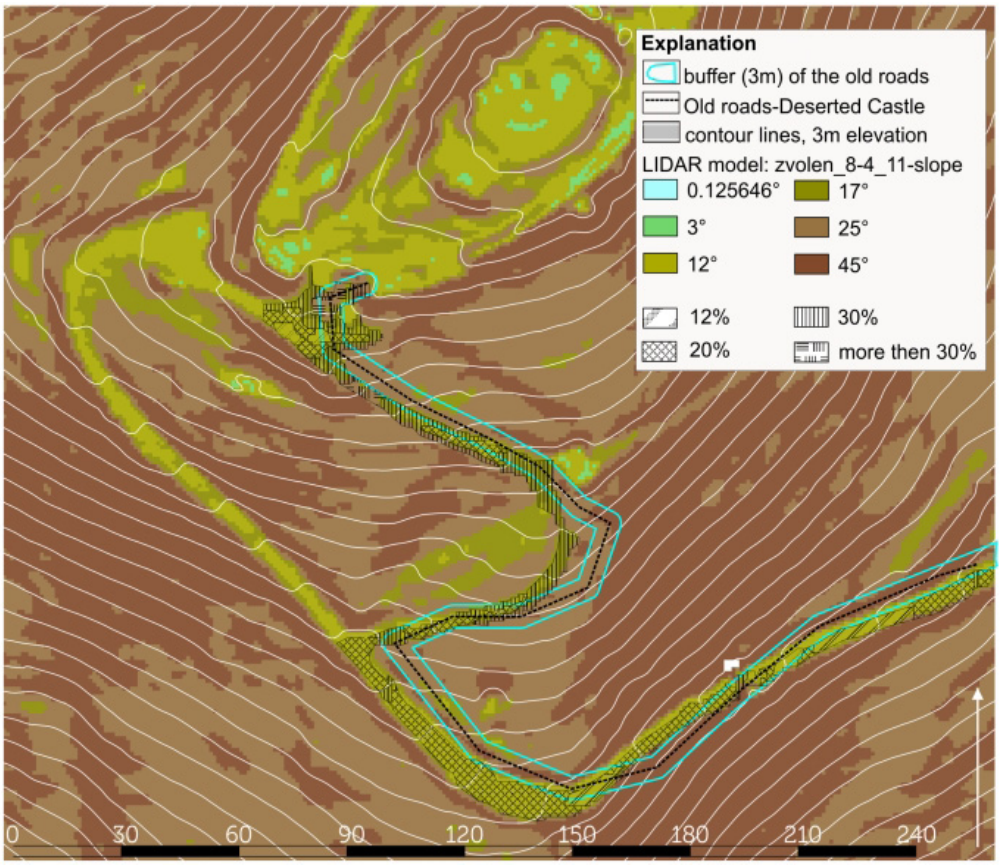

Fig. 3. Comparison of geographic position about historical road identified by GNSS and by LIDAR technology (slope grade derivation).

The system of valleys with steep slopes, generally more than 17° and locally above 25°, with rocky cliffs above the river Neresnica and Hron and high mountain backs (elevation from the valleys bottom is nearly 200-250 m) provided natural barriers for potential enemies in the Middle Ages. On the other hand, mountains created barrier for merchants and common people travelling to Zvolen. There was permanent risk of floods in the narrow valleys with wild rivers and this is the reason why people established historical road network in the mountains (Ivanic, 2011). It is also the case of the presented area around Zvolen, around the Deserted castle. As Kvet, Rehak (1993) mentioned, knowledge about geomorphologic forms is crucial for understanding the defence system of fortresses and castles which controlled areas with historical roads. We confirmed this finding. Roads are located mostly on the mountain slopes or in the mountains valleys. The main function of the medieval road network was providing the most comfortable connection between the settlements. Very important is their vertical profile. They have smooth ascending and descending profiles with minimum steep parts. Accessibility of roads for animals with heavy cart-loads was the main limiting factor for location of the historical roads. The most important category of slope grade in forestry engineering is less than 12% (less than 6,84°) for the roads of primary category, thereafter is important the second category: 12-20% (6,84°-11,31°); 20-40% is limit for the terrestrial mechanism (Klc, Novak, 2006). Austrian forestry literature indicates that during the 17th century were built roads in the mountains and their parameters are in coincidence with contemporary standards for technical construction of forestry roads (Rosko, 1984). The same situation we observed in the field. Dusan Fertal identified new roads which correspond with historical ones.

Discrepancy of data in horizontal and vertical accuracy is caused by low precision of GNSS devices in the category of touristic GNSS systems which we used (manufacturer's specified positional error in point determination is 3 m in case of low signal). We need to note that terrestrial measurement by GNSS of the historic roads in studied area was carried out under the high trees with crowns canopy and it could cause not only weak signal, but also no signal to some active satellites ("visible" at the time of measurement) which are using on position calculation. It could lead to worse position error than is declared by GNSS producer. The model laser scanning has proclaimed horizontal and vertical accuracy of the points, between 0,20 – 0,10 meters. If we want to improve the accuracy of the terrain measurement of the linear historical objects under the forest cover in the future, we should use the GNSS system with longer time of observation of the geodetic position. Contemporary satellite geodesy verifies the measurements in areas with low or no signal from existing satellite of systems (NAVSTAR, GLONASS) and the measurement using geostationary satellites with using service TERASTAR. In cases the natural relief barriers and dense forest crowns do not allow us to use GNSS, it is possible to combine satellite measurements with electronic tachymeter's measurements. Therefore is necessary to consider the purpose of subsequent use of the results and the expected final accuracy before each measurement and important is to choose correct GNSS device (GIS devices).

6.Conclusions

The road network around Zvolen has been the entrance gateway to the mining areas of the central Slovakia since the prehistory and this function has been lasting for medieval times. All the main entrance roads led across the Zvolen town from the South and West and traversed surrounding mountains which are covered by forests. The Deserted castle in Zvolen, as well as the Zvolen town was vulnerable particularly from the forests to the South, where historic access roads are located on the hillsides. There was necessary to protect these roads by the system of fortifications for the security reasons. By this way the Deserted castle had key strategic function to keep watch on the entrance points on the road system. The road system is strongly related to the historical settlements which are indicated according to the archaeological sites. Analysis of the settlements origin and location in the landscape help us determine the age of historical roads and identify their function. That research is interesting mostly for identification of objects dated to early Middle Ages which are only sporadically or not mentioned in the historical materials.

Today, influence of the non-contact objects measurement is increasing in the fields of geology, landscape ecology and archaeology. Aerial laser scanning is used widely as additional method to the photogrammetric method of quantitative mapping. According to gained knowledge, we can conclude that aerial laser scanning method is suitable for mapping of anthropogenic relief forms and also areas covered by forests. The best scanning period is calm growing period (early spring without snow, because snow does not allow back reflection of emitted rays), when most of the plants are without assimilation organs, grasslands are low and the emitted beam can penetrate to abiotic terrain. Scanning services, in certain conditions, has been getting progressively cheaper and more applicable in practice with acceptable financial price. It is very important argument for the use of modern methods.

Forests should not provide only production functions but they should be managed also as recreational zones. Revitalization of the historical roads in landscape is solved in several projects of the European cultural routes[1]. We recommend that no human activities should be intensified in both antecedent valleys because they could destroy unique landscape character. We have ambition to apply our results into the field of soft tourism activities in the forest environment in the future.

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Acknowledgements

We would like to give a special thanks to our colleague Dusan Fertal who was the initiator of the field mapping. His skills and knowledge helped us to identify and understand the historical road system in landscape. Authors would like to give thanks for financial support of the paper elaboration to the KEGA grant agency, project no.011TUZ-4/2012 (80%), and UGA UKF grant support, project no. I/23/2012. This publication is the result of the implementation of the project: Centre of Excellence "Decision support in forest and country", ITMS: 26220120069, supported by the Research & Development Operational Program funded by the ERDF.

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